# FEA module content

## Introduction to FEA

Competencies

Lesson Notes

- A Simple Definition
- Outline of the Analysis Process
- Skill and Experience
- A Brief History

Self Test Quiz: 10 Questions

## Trends in FEA

Competencies

Lesson Notes

- Analysis Methods
- Trends in Technology
  - *Introduction*
  - *Hardware*
  - *Model Detail and Complexity*
  - *Optimisation*
  - *Nonlinear Analysis*
  - *Multi-Physics*
  - *Multi-Scale*
  - *Non-Deterministic*
  - *Validation*
  - *System Development*
- Conclusions

Self Test Quiz: 12 Questions

## Theoretical Background

Competencies

Lesson Notes

- Classification of Finite Element Methods
- The Displacement Method
  - *Outline*
  - *Choice Of Displacement Functions*
  - *Matrix Process Outline*
  - *Gaussian Quadrature*
  - *Distributed Loading*
  - *Solution Of System Matrices After Assembly*
  - *Further notes on element stiffness matrices*
- Convergence - The Patch Test
- Curved Isoparametric Elements
  - *Displacement Assumption*

Self Test Quiz: 30 Questions

## Basic Modelling

Competencies

Lesson Notes

- Basic Modelling
  - *FEM Flowchart*
  - *Equation of Element Stiffness Discretization*
    - *Symmetry*
    - *Choice of Element Type*
    - *Node Location*
    - *Element Size, Shape etc*
    - *Equivalent Nodal Loading*
    - *Techniques for Large Models*
  - Element Selection
    - *The Element Library and Typical Uses*
    - *Spring, Mass, Gap and User-defined*
    - *Bars and Beams*
    - *Axisymmetric Thin Shell*
    - *2D Plane Stress and Strain*
    - *2D Solid of Revolution*
    - *Membrane*
    - *Plates*
    - *Shells*
    - *Solids*

Tutorials (4)

- Edge loaded circular plate
- Bending of a deep curved beam
- 3D Plane stress elliptical membrane
- Hole in an infinite plate

Worked Examples (8)

- Thick cylinder under various loadings
- Small pipeline under IPB
- Cylindrical shell with elliptical opening
- Local reinforcement to a flat plate
- Hole in a plate of finite width under tension
- Membrane stresses in pressurized torus, cone, cylinder, sphere
- Axisymmetric domed plate with varying radius
- Cantilevered beam under bending

Self Test Quizzes: Basic Modelling (20 Questions)
Element Selection (26 Questions)

## Model Extents, Symmetry and Boundary Conditions

Competencies

Lesson Notes

- Model Extents, Symmetry and Boundary Conditions
  - *Model Extents*
  - *Boundary Conditions*
  - *St. Venant's Principle*
  - *Decay Lengths in Shell Structures*
    - *Discontinuity Stresses in Cylinder / Shallow Sphere Junction*

*Discontinuity Stresses in Cylinder / Cone Junction Discontinuity Stresses in Cylinder / Hemispherical Junction Discontinuity Stresses in Cylinder / Torispherical Junction Discontinuity Stresses in Spherical Vessel*
*Ovalization in a Mitred Pipe Bend*
*Stresses in a Pressurized Nozzle / Sphere Junction*
*Stresses in a Pressurized Nozzle / Cylinder Junction*
*Stress Decay in a Ring Loaded Cylinder*
*Deformation at the Base of Storage Tank*
*Local and Gross Stress Concentration*

Symmetry Techniques
*Introduction*
*Symmetrical Boundary Conditions*
*Asymmetrical Boundary Conditions*
*Unsymmetrically Loaded Structures with Geometric Symmetries*
*Cyclic Symmetry*
*Conclusions*

Tutorials (5)

Hemishpherical shell with point loads
Axisymmetric shell under internal pressure (drinks can base)
Thermal stress analysis of solid cylinder sphere junction (temperatures given)
Edge loading of a cylindrical shell
Axisymmetric stiffened cylinder under internal pressure

Worked Examples (6)

Axisymmetric hyperbolic shell under internal pressure
Pressurised cylinder with a spherical head
Axisymmetric cylindrical vessel-skirt junction
A hemispherical shell with edge loading
Pressurized cylinder with a step in outside diameter
Circular plate with variable boundary conditions

Self Test Quiz: 19 Questions

## Approximations and Sources of Error

Competencies

Lesson Notes

Types of Error
*Types of Error*
*User Mistakes*
*Discretization, Idealization or Modelling Errors*
*Numerical or Computational Errors*

Sources of Error and Physical Causes
*Element Shape*
*Information Truncation*
*Incompressible Elastic Media*

Detecting Errors
*Condition Number or Range of Eigenvalues*
*Decay of Diagonal Coefficients*
*Residuals and Iterative Improvement*
*The K-1R Criterion - Engineering Appraisal of Error Forces*
*The Diagonal Energy Criterion*
*Variance of the Total Strain Energy*

*The Range of Diagonal Coefficients*
*Concluding Remarks on Detecting Errors*

Reducing the Effect of Errors
*Reducing the Effect of Errors*
*Symmetry*
*Stress Concentration*
*Increased Arithmetic Precision*
*Convergence*

Self Test Quiz: 18 Questions

## Further Modelling Considerations

Competencies

Lesson Notes

Modelling Shell Intersections
*The Nature of Shell Intersections*
*Model Improvement Techniques*
*Illustrative examples of typical intersection stress distributions*

Hybrid modelling
*Introduction*
*Some examples of hybrid modelling*
*Stiffened plates and shells*
*Axisymmetric lined vessel*
*Axisymmetric Thin Vessel with Internal Radial Plates*
*Axisymmetric Vessels with Hoop Stiffeners*
*Axisymmetric Thick Vessel with Internal Radial Plates*
*Axisymmetric Flat End Closure*
*Further Notes on Modelling Stiffened Shell Structures*
*Various Discrete Stiffener Models*
*Conclusions*

Axi-Fourier Analysis
*Introduction*
*Fourier Series Background Mathematics*
*Fourier Series Background Mathematics*
*Functions Having Arbitrary Period T*
*Even and Odd Functions*
*Finite Element Theoretical Background*
*Finite Element Theoretical Background*
*The Stiffness Matrix*
*Nodal Forces*
*Line Loads and Point Loads*
*Point Loads*
*Reactions*
*Stresses*
*Illustrative Examples*
*Gravity loading of a Thick Tube*
*Pinched Cylinder with Free End*
*Conclusions*

Modelling and Assessing Welds
*Modelling and Assessing Welds*
*The Goal*
*The Challenges*
*A Note on Singularities*

*The Techniques*
*Shell idealisation*
*Solid idealisation*

Tutorials (5)

Elastic analysis of a U-shaped pipe bend
Shell to solid submodelling/coupling of a pipe joint
Gravity Loading of an Axisymmetric Cylindrical Shell
PD5500 single lap joint weld stresses
Reinforcing plate with perimeter weld – weld and connectivity study

Worked Examples (9)

Model of a bolted pipe flange
Gravity loading of a thick tube
Pinched cylindrical shell with free ends
Elastic analysis of a flush cylindrical nozzle in a spherical vessel
Large fabrication containing intersections
A stiffened flat plate
Cantilevered beam with asymmetrical boundary conditions
Pressurized cylinder with a flat end closure
Hybrid modelling of a shell intersection

Self Test Quiz: 22 Questions

**Practical Guidelines**

Competencies

Lesson Notes

Practical Guidelines
*Management of FEA, including V&V*
*Useful Pro-forma Sheets*
*The Interface between FEM and CAD*

Common Basic Issues

Self Test Quiz: 10 Questions

**TOTALS**

***9 Quizzes with 167 Questions***

***14 Tutorials***

***23 Worked examples***